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ABSTRACT

Recent dramatic developments in brain research and technology suggest that a comprehensive understanding of how the human brain works may soon be within reach. Just as the ability of the medical profession to treat patients improved dramatically with the advent of effective research skills and technology concerning the structure, biochemistry, and functions of the body, so the ability of the educational profession to teach students should improve dramatically once new knowledge replaces the traditional folklore of education. Among the recent critical developments in brain study have been major discoveries about molecular changes that occur within individual neurons when learning and memory take place, significant findings related to the architecture of brain networks and the effects of neurotransmitters, and improvements in brain imaging machines made possible by advances in computer technology. To respond effectively to this new knowledge, educators must become informed about neuroscientific concepts. The teaching of such concepts should be included in teacher education programs and made available through inservice education. (PGD)

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Dramatic Developments in the Neurosciences Challenge Educators

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Recent dramatic developments in brain research and technology suggest that a comprehensive understanding of how the human brain works may soon be within reach. The arrival of such an understanding will pose a major challenge to educators, who have had to operate with a limited understanding of the organ that, above all others, defines their profession.

In this article I will describe several key factors that have sparked the recent rapid increase in neuroscientists' understanding of brain mechanisms and processes. I will also identify and discuss several important educational issues that are arising out of these developments. Implications for preservice and inservice training will be highlighted.

The Neuroscience Research Dilemma

The human brain is the best organized three pounds of matter in the universe. Nevertheless, the brain's awesome complexity has always been a barrier to its study and understanding. Until recently, researchers lacked the technology to study many key brain functions, and so progress in the neurosciences was slow and tentative.

The brain's cellular units are tiny, the numbers are immense, and everything is interconnected. At the cellular level the human brain's three-pint mass is divided somewhat evenly between an estimated thirty billion neurons (that monitor and regulate cognitive activity) and the much smaller and ten times more numerous glial cells (that provide the support, insulation, and nourishment neurons need to function efficiently.

To grasp the numbers involved, consider that the average human head has about 100,000 hairs; thus thirty billion neurons could be represented by all the hair in the city of Portland. Since a space the size of a pinhead can contain more than 30,000 neurons, brain researchers obviously had problems when they tried to sort out the electrochemical activity of individual neurons.

Studying the combined activity of aggregates of related neurons was equally difficult. For example, the 200 million nerve fibers that form the corpus callosum--which links the brain's right and left hemispheres--process several billion bits of multiple-level information every second.

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If the human brain's awesome complexity hindered research in the neurosciences, its elegant simplicity enhanced its study. Our brain has to be simple, adaptable, and predictable to function continuously over an extensive human lifespan. Scientists set out to create the research technology that would permit them to study the actions of a single neuron, the synchronized activity of aggregates of related neurons, and the factors that trigger and intervene in neural activity.

In studying the brain, scientists have followed a multiple-level research agenda. Recently, discoveries on three major levels of inquiry--animal neural systems, human brain malfunctions, and computer brain imaging devices--have advanced our understanding of the mechanisms/processes that regulate learning and memory. Each of these advances has important implications for education.

Simple Neural Systems. Since basic neural functions are similar across all organisms with a nervous system, scientists who sought to understand basic neural processes focused--for ease of study--on animal brains. Particularly they selected animal brains having large neurons, simple neural systems, and a limited behavioral repertoire. Almost three decades of extensive study of two marine snails, Applysia and Hermissenda, have recently led to major discoveries on the molecular changes that occur within individual neurons when learning and memory take place. It's an important first step for our profession to understand the basic biochemical processes that we affect through our teaching. In time, we may learn how to manipulate these processes to enhance learning.

Brain Malfunctions. Other scientists focused on various learning and memory disorders. By studying structural and chemical malfunctions, these scientists hoped to discover how learning/memory systems work. A major discovery that came out of this research is that people who have Alzheimer's Disease typically exhibit a significant loss of neurons in a small area deep within the brain that produces much of the brain's supply of acetylcholine, a neurotransmitter associated with memory circuits.

The researchers also found that Alzheimer's patients have blockages in neurons in the nearby hippocampus; these neurons project into brain areas that process conscious memories and actions. The hippocampus is a fingersize structure that apparently is to long-term memory what a card catalog is to a library.

Discoveries such as these provide us with a better understanding of the neuromechanisms that interact to assemble and regulate memory networks. In time these discoveries may provide educators with a clearer picture of the ways in which learning disabilities relate to network architecture and neurotransmitter levels.

Brain Imaging Technology. Recent developments in computer technology have led to dramatic improvements in brain imaging machines. These devices have revolutionized the study of interconnected areas within the living active human brain that play key roles in learning/-memory. Brain imaging machines can travel through the skull to specific brain areas to gather, rapidly process, and report the vast amounts of electrochemical data that the human brain continuously creates. The machines then translate these data on electrical, chemical, or blood flow activity into high resolution, three-dimensional, colored, TV screen representations of the brain.

One such noninvasive machine, BEAM (Brain Electrical Activity Mapping), has disclosed patterns of activity associated with dyslexia and serious emotional disturbance. BEAM technology should soon be within the financial reach of school systems. It will provide trained educators with a powerful tool for the diagnosis and treatment of learning and behavioral disorders.

(My research synthesis, "Research on Memory: Major Discoveries, Major Educational Challenges," in the April 1985 issue of *Educational Leadership* provides a more extensive description of recent developments that relate to the neuromechanisms and processes that regulate learning/memory.)

The Education Profession's Dilemma

The education profession couldn't wait until the neurosciences blossomed before deciding how to teach. We had to respond to the students who daily arrived at the school door--whether we understood how their brains functioned or not. The result was that our profession tended to focus its research energy on behavior--the visible/measurable/pliable manifestation of cognitive activity--rather than on cognitive mechanisms and functions.

Behavior has served us surprisingly well over the years. Practitioners and educational researchers have observed students carefully and statistically over time, with the result that a solid body of normative practical knowledge about teaching and learning gradually evolved.

To be honest, though, much of this knowledge was professional folklore. We could predict what would probably occur in a classroom, but we generally didn't know why. For example, we knew that more boys than girls had reading problems, and that hyperactive children tended to be thin, blond, blue-eyed boys--but we didn't know why. The result has been a tendency within the profession to reach inappropriate generalized conclusions (for example, that boys are stupid and ill-mannered). We also have a gnawing feeling that we can't be sure whether our students learn because of or despite our efforts.

Perhaps a more serious issue is that the study of behavior can lead educators to only a partial diagnosis and treatment of many complex learning problems that we've been relatively ineffective in solving (for example, dyslexia, attention disorders, motivation, forgetting). Schools tend to be most successful with students of better than average ability, who can function reasonably well without much teacher assistance.

In a similar vein, the medical profession operated at the level of professional folklore and ill-understood remedies for most of its long history. It likewise wasn't very effective in treating health problems that went beyond those that the normal body's own recuperative powers could heal with time and rest. The medical profession's move to the successful diagnosis and treatment of complex health problems began relatively recently, when it developed the research skills and technologies it needed to study the structure and biochemistry of the body and its organs. We'll need to do the same if we expect to diagnose and treat complex learning problems. We can't expect others to focus their efforts on our research problems. We need to encourage bright young educators to develop the scientific background that will equip them to study the educational applications of neuroscience research.

The medical profession upgraded its researchers and practitioners with sound scientific and technological preservice/inservice programs when it discovered that medical folklore wasn't its only option. We ought to do the same, and it's not an impossible task. The human brain is awesomely complex, but it's also elegantly simple. It's the only three pounds of matter in the universe that can contemplate itself--and so any reasonably intelligent brain ought to be able to understand its own basic mechanisms.

Can a profession whose charge is defined by the human brain continue to remain uninformed about it? If we do, we will become vulnerable to all the pseudoscientific fads, generalizations, and programs that will surely arise. If we can't take informed leadership on complex educational issues that are already arising out of this research, we can expect that other (and possibly equally uninformed) people will make our decisions for us.

Educators Must Inform Themselves about Neuroscience Concepts

It's unfortunate but understandable that many in our profession today lack the natural science background to understand neuroscience research, let alone to participate in it, or to create curricula around it. What can be done to remedy this situation?

Preservice Education. It's a rare teacher education student who takes much academic work in biology, chemistry, and cognitive psychology. The typical student in the University of Oregon's elementary teacher education program currently takes 12-16 quarter hours of science in a 186-hour undergraduate program.

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Our profession has been oriented in the social and behavioral sciences. Although this preservice focus was perhaps appropriate within the traditional view that classroom teaching focuses on negotiated activity within a group setting, we must increase the amount of natural science in our professional preparation if we expect the next generation of teachers to understand the brain that defines their assignment.

How can we add hours to an already packed program? The University of Oregon is currently thinking about a five-year teacher education program that should open the program to such

curricular enrichment. In the meantime, we are introducing our elementary-level students to basic neuroscience concepts that relate to teaching/learning in a required eight-hour block course that I teach. We also encourage students to take biology, chemistry, and cognitive psychology courses as a part of their University general education requirements. It's a beginning.

Inservice Education. A half- or full-day inservice workshop that uses nontechnical language to introduce educators to basic neuroscience concepts and issues can be an interesting and important beginning (or update), but it can also be not much more than that. I do many of these workshops in the course of a year, and I sometimes feel that my major long-term contribution to the group may have been that I got some of them (1) to begin to monitor such magazines as *Discover, Science 86, Psychology Today,* and *Science Digest*; and such TV programs as Nova and Innovation for educationally significant developments in the neurosciences; (2) to buy and read some of the excellent inexpensive books currently available for general readers; and (3) to pass on what they learn to their students--because many teachers tend to turn new information they gather into knowledge only by teaching it.

Schools ought to purchase and place such books and magazines in their professional libraries, to videotape TV programs that focus on brain research, and to discuss issues/implications during staff meetings. A relatively small investment in materials can pay major professional dividends over time if the staff is encouraged to engage in self-study.

A district's science teachers are an excellent (and often overlooked) staff development resource in this field. Many biology/-chemistry/psychology teachers are intensely interested in and informed about neuroscience research. A modest grant for additional summer study or a sabbatical leave for a good science teacher could provide your district with an extensive inservice program that could develop beautifully over several years.

Conclusion

The education profession is at the edge of a major transformation. Scientific knowledge of how the brain works and awareness of educational issues that arise out of such knowledge will only increase. Additional important discoveries can be expected in learning/memory, hemisphericity, the nature of intelligence, the effects of drugs, neural transplants, electronic implants, the effects of intellectual enrichment on brain development, and the list goes on.

Imagine the fix we'd be in today if the medical profession had decided to remain at the level of professional folklore and home remedies when it was at its analogous point of decision. By informing itself of the scientific foundations of learning, the education profession will be able to approach its task with renewed ability and confidence.

Suggested Materials for the General Reader

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